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IMPACT ASSESSMENT OF DIJKOT BRANCH DRAIN EFFLUENT ON GROUNDWATER QUALITY USING GIS TECHNIQUE

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Pollution through the industry is a very serious issue in all over the world and especially in Pakistan. Industrial effluents polluting the water resources directly and indirectly as well. Furthermore, it also affects the soil properties and crop yield. Here is the investigation of wastewater from Dijkot branch drain performed near the area of Gojra (Dawakhri). The aim of this study was the cheek the flow rate of drain, effluent contamination and their effect on groundwater with spatial variation and plan for safe groundwater extraction. The groundwater sample was taken from different thirty points for the analysis of groundwater and five samples were taken from the drain (wastewater + sludge) for checking the effect on groundwater. The average flow rate concentration was 1.996 m^3s^{-1}. Chemical analysis performed for the groundwater study showed the results for pH 8.0 ± 0.14, Electrical conductivity (EC) 2375.8 ± 5.8, Total dissolved solids (TDS) 1580 ± 4.0, Total suspended solids (TSS) 584.7 ± 2.81, Chloride contents 342 ± 3.38, Sodium adsorption ratio (SAR) 71.50 ± 3.1, Residual sodium carbonate (RSC) 5.79 ± 0.92 and Total hardness (TH) 503.09 ± 2.92. For wastewater results were for pH is 9.17 ± 0.15, Total dissolved solids (TDS) 7627 ± 4, Biological oxygen demand (BOD) 290.6 ± 1.90, Chemical oxygen demand (COD) 395.4 ± 2.45 and Heavy metals i.e., Cadmium (Cd) 1.21 ± 0.092, Lead (Pb) 0.80 ± 0.091, Cooper (Cu) 0.016 ± 0.02, Chromium (Cr) 1.50 ± 0.23 and for Zinc (Zn) 4.64 ± 0.50. For sludge analysis results were for pH 9.17 ± 0.013 and Heavy metal showed the results i.e., Cadmium (Cd) 1.19 ± 0.09, Lead (Pb) 0.67 ± 0.1, Cooper (Cu) 0.017 ± 0.02, Chromium (Cr) 1.6 ± 0.13 and Zinc (Zn) 4.74 ± 0.49. The results showed the higher concentration of chemical parameters for groundwater was found due to the high concentration of wastewater and sludge effluents. As a whole the conclusion of this research showed groundwater was not good for drinking purposes moreover the quality of groundwater is also not fit for the irrigation purposes also. Industrial effluents are adversely affecting the cropping area directly and indirectly.

Keywords: Polution, Industrial effluents, Ground water, Electrical conductivity (EC), Sludge, Chemical oxygen demand (COD), Heavy metals

INTRODUCTION

The establishment of unplanned industrial units has increased the pollution threat in soil of Pakistan. Due to this situation the outcomes include degradation of soil and irreversible extinction of many sensitive species, decrease in biodiversity and more importantly it has affected adaptability of organisms for selection. After the Qasoor disaster and other such types of disasters, the government of Pakistan became conscious for the safety of environment and now it has approved that to establish new industry, proper planning regarding the safety of environment should be done (Morel *et al*., 2005).

Pakistan's agriculture has been suffering occasionally, from severe shortage of irrigation water in the recent past. The surface water availability at canal heads was 103.5 MAF during 2008 which decreased to 82.2 MAF during 2012 (MINFAL, 2007). To augment the irrigation supplies, another non-conventional source of irrigation is the municipal sewage effluent, which itself contains heavy metals in addition to soluble salts, plant nutrients, pathogens and suspended particulate matter (Hussain, 2000). Because of ambient shortage of irrigation supplies, urban agriculture soils are usually irrigated with untreated city effluents for growing agriculture crops, mostly vegetables.

The waste water from the domestic and industrial areas is disposed into the same sewer system, later such effluent will be known as raw effluent. Farmers use it as a source of irrigation and nutrients (Ghafoor *et al*., 2005) while administrators consider it a vital option for disposal. According to survey about 62000 hectares around Faisalabad and 93000 hectares in Multan were irrigated with the raw effluent for growing the agriculture crops.

Out of which 11.5 MHA is salt affected (FAO, 2005). With increasing industrialization and population growth, different materials are discharged into sewage. These often lead to environmental pollution as earlier studies reported that the

raw effluent released into unlined drains are creating problems such as soil salinity/ sodicity and metal ion toxicity for agriculture (Aziz, 2001).

This condition in Pakistan is a big point in pollution case. In Pakistan, the population has grown rapidly. It is expected that the population of Pakistan will increase from 156 million in 2000 to 263 million by 2025. By that time, about 50% of the population will be living in urban centers, with majority living in the Indus river basin that supplies water to the largest system of irrigation in the world. It is estimated that 25-35 million people in the Indus basin live in areas with very low rainfall and with groundwater that is brackish in color. Therefore, they depend on surface irrigation water for all their water needs, including drinking, bathing and washing. In many towns of Pakistan, a system of sewage disposal exists, but its' waste water is used for irrigation. While in those cases where waste water is used indirectly, it is mixed in the easiest way in surface water bodies, which often are irrigation canals that serve as the source of drinking water for people further downstream. However, the amounts of waste water that are dumped off and used are unknown in most cities (Hoek *et al.*, 2002).The wastewaters from agro-industrial activities, as a sub-class of waste waters from industry have considerable effect on the environment. The amount of waste water that is being generated by industrial processing is huge, and in terms of strength of pollutant, it is very strong. For example, citing ASEAN countries in Asia, waste water of agro-industry significantly contributed in the pollution load. It has been studied that in 1981 the contribution to BOD (Biochemical Oxygen Demand) in Malaysia by Malaysian palm oil was 63% (1460 td-1) per day and rubber industries was 7% (208 td-1) per day. In comparison, this is greater than the generation by domestic sewage, which may generate 715 td−1 of Biochemical Oxygen Demand. Similarly, in the Philippines, paper and pulp mills produced 90 td-1 of Biochemical Oxygen Demand (BOD) load (Takeda, 2004).

With the higher concentration of heavy metals, mutations in genetic material and tumor in animals have been induced. Their compounds have ability to cause damage in genetic makeup, especially in germ cells of female and male in animals and humans beings (He *et al.*, 2005). They are regarded as cumulative toxins which through bio-magnifications in plants, affect human health. It was published that heavy metals mixed in soils are then adsorbed by particles of soil and later, are leached into ground water. These heavy metals are being accumulated in human beings in the form of ingestion of contaminated food and intake of dirty water. Similar condition exists in plants and in other animals (Khan *et al*., 1996).

In plants, the heavy metals like Lead (Pb), Nickel (Ni) and Cadmium (Cd) are considered as highly toxic metals even at low concentrations. The toxicity of heavy metals occurs by complex interaction with other non-essential or essential ions and major toxic ions. The hydrolysis of products can be reduced by these heavy metals viz., phosphatase, proteins, α-amylase and RNAs. They interrupt in the action of enzyme by substituting the metallic ions from the metalo-enzymes and stop the many physiological related processes in plants (Agarwal, 1999).

MATERIALS AND METHODS

Sampling: The sampling area was selected near Dawakhri along the Dijkot branch drain as shown in Fig.1. Wastewater and sludge sample were collected from the drain in quantity 1 liter and 500 gram respectively. The groundwater samples were collected from both sides of the drain having distance varying within a range of 600m. Samples were preserved in 4ºC immediately so that no chemical change takes place (Nosheen et. al., 2000).

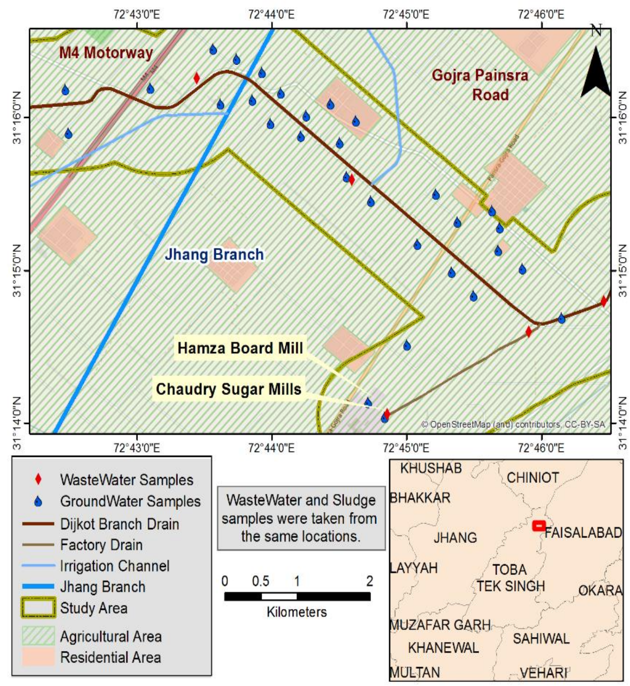

Figure 1: Area of study and Sampling point

Analysis: pH and EC was measured by using pH meter and EC meter, respectively. TDS and TSS was measured by using oven dry method as described in (Greenberg, 1992). RSC and SAR was measured by titration method, using formulae as described respectively:

$$SAR = Na / [(Ca + Mg)/2]$$

$$RSC = (HCO_3 + CO_3) - (Ca + Mg)$$

Chloride contents and Total Hardness (TH) was measured by using titration method. For wastewater, BOD5 was measured by using incubation for 5 days and COD was determined by using heating plate and then titration. Heavy metal analysis was performed on atomic absorption spectrometer (AAS) by using flame method (Greenberg, 1992).

RESULTS AND DISCUSSION

Wastewater and sludge analysis was performed and showed the worse condition of drain. The effluents are coming from the sugar mill industry and board mill are toxic. Discharge rate was calculated for two days with the 2 hour interval during the day time and results showed that the effluents were discharged at high rate ranging between 1.88 m^3s^{-1} to 2.3 m^3s^{-1} (Table 4). Geographical map of wastewater and sludge was same and shown in Fig 9. The hydrogen ion concentration pH for wastewater and sludge was same during the analysis ranging 8.9 to 9.89 (Ghannam *et al.,* 2012). Whereas the mostly groundwater samples showed high concentration of pH varies between 7.8 to 9.10 while only three samples showed less concentration that was 6.80 to 7.5 (Table 1). These samples were taken away from the drain up to 510 m. Geographical interpolation of groundwater samples shown in Fig 1 that represents high level of alkalinity in groundwater which is toxic and unsafe for soil as well.

Electrical conductivity was analyzed for thirty samples of groundwater five different samples of wastewater and sludge. Groundwater samples showed the range between 239 µS/m to

Table 1: Analysis of groundwater samples taken along the drain

Sr. #	Location	Longitude (E)	Latitude (N)	pH	EC	TDS	TSS	Chloride	SAR	RSC	TH
1	GWS 1	72.76238	31.25276	7.71	931	465	227.85	80	47.02	2.94	370
2	GWS 2	72.76074	31.25599	6.82	3209	1612	789.88	498	66.38	5.39	900
3	GWS 3	72.76035	31.25619	7.15	712	356	174.44	120	97.82	2.51	353
4	GWS 4	72.75628	31.25533	7.65	3414	1706	835.94	312	45.14	7.69	500
5	GWS 5	72.75237	31.24900	7.12	1044	518	253.82	320	69.22	2.49	603
6	GWS 6	72.74534	31.23995	8.02	1703	859	420.91	170	93.08	5.29	513
7	GWS 7	72.74733	31.23398	8.01	831	418	204.82	101	55.35	1.79	517
8	GWS 8	72.74526	31.23559	8.65	239	122	59.78	32	2.57	1.14	75
9	GWS 9	72.76919	31.24481	8.02	3620	1835	899.15	501	15.36	7.63	1043
10	GWS 10	72.73638	31.26199	8.38	907	481	235.69	135	89.44	2.53	335
11	GWS 11	72.74258	31.26023	9.10	598	288	141.12	106	119.41	0.89	334
12	GWS 12	72.75593	31.25096	8.36	4500	2250	1102.5	672	86.10	8.39	187
13	GWS 13	72.75717	31.24967	8.16	6020	3010	1474.9	791	59.51	8.77	1700
14	GWS 14	72.76163	31.25405	7.76	1569	783	383.67	301	30.66	3.24	509
15	GWS 15	72.76221	31.25096	7.86	5510	2750	1347.5	960	116.24	13.29	456
16	GWS 16	72.75715	31.25754	8.30	1859	908	444.92	693	39.73	5.90	637
17	GWS 17	72.75739	31.25851	8.45	3072	1533	751.17	618	88.05	6.15	519
18	GWS 18	72.73333	31.26932	8.05	2466	1231	603.19	542	73.75	8.48	488
19	GWS 19	72.73296	31.26938	8.08	878	437	214.13	210	62.42	2.34	220
20	GWS 20	72.72897	31.27197	8.31	4790	2400	1176.0	604	26.49	8.49	570
21	GWS 21	72.72609	31.27417	8.26	2224	1108	542.92	232	49.08	6.92	496
22	GWS 22	72.72763	31.26700	8.01	2820	1419	695.31	240	22.51	9.22	382
23	GWS 23	72.71757	31.27009	8.07	5090	2550	1249.5	668	166.33	15.62	332
24	GWS 24	72.70707	31.26478	8.02	992	495	242.55	102	118.88	4.45	190
25	GWS 25	72.70756	31.26398	8.53	2910	1452	711.48	210	90.85	6.61	420
26	GWS 26	72.73186	31.26936	8.44	448	224	109.76	38	113.97	0.36	356
27	GWS 27	72.73204	31.26916	8.04	3432	1718	841.82	438	73.74	10.04	704
28	GWS 28	72.73178	31.26904	8.11	1423	708	346.92	177	70.97	5.58	410
29	GWS 29	72.73374	31.26744	7.70	1457	715	350.35	98	93.65	6.70	276
30	GWS 30	72.73368	31.26754	6.80	2606	1299	636.51	291	61.29	2.73	876

Table 2: Analysis of wastewater samples collected from drain

Sr. #	Location	Longitude (E)	Latitude (N)	pH	EC	TDS	COD	BOD	Pb	Cr	Cu	Cd	Zn
1	WWS 1	72.74732500	31.23398333	9.20	8140	5200	435	332	0.81	1.20	0.03	0.90	4.20
2	WWS 2	72.74525556	31.23559444	9.53	6040	3805	485	289	0.79	1.00	0.01	0.77	3.80
3	WWS 3	72.76918611	31.24481389	9.10	8060	5200	260	201	0.91	1.80	0.02	1.30	5.20
4	WWS 4	72.73637500	31.26199444	8.99	8001	5008	332	309	0.8	2.10	0.01	1.50	5.10
5	WWS 5	72.74257778	31.26023056	9.07	7894	4978	465	322	0.7	1.40	0.01	1.60	4.90

6020 µS/m (Table 4) whereas the samples of wastewater and sludge showed the range between 3805 µS/m to 5200 µS/m and 5098 µS/m to 8178 µS/m (Ghannam *et al.*, 2012 and Adamu, 2012) respectively. Geographical interpolation is shown in Fig 10 for wastewater and Fig 11 for Sludge. Geographical interpolation of groundwater samples for Electrical conductivity shown in Fig 2 that represents high level of salt concentration in groundwater which is clarify the high level of salinity soil and groundwater.

Total dissolved samples (TDS) level for the wastewater sample showed high concentration ranging between 6040 mg/L to 8140 mg/L (Table 4), and samples of groundwater ranging from 122 mg/L to 3010 mg/L (Rajaganaish *et al.*, 2014). Some samples that were near the Jangh branch canal showed very less amount of TDS while mostly samples have TDS level above than the permissible limit prescribe the NEQS. Fig 3 and Fig 12 showed the GIS interpolation of TDS for different samples of groundwater and wastewater respectively.

Total suspended solids (TSS), chloride content and total hardness for the groundwater samples except those samples collected from near the Jangh branch canal showed very worse condition. TSS, chloride contents and total hardness varies in the range between 59 to 1474 mg/L, 32 to 960 mg/L and 75 to 1700 mg/L (Imtiazudin *et al.*, 2012) respectively (Table 4). Such samples results showed the poor condition of groundwater for the drinking purposes. Total hardness was cheeked for the samples of groundwater as the major analysis for water quality parameters and results showed the range between 75 mg/L to 1700 mg/L (Adamu, 2012). The level of total hardness above the 250 mg/L is not suitable for the drinking purposes. Fig 4, Fig 5 and Fig 6, showed the geographical interpolation of total suspende solids, chloride contents and total hardness. Total hardness showed the (Ca^{+2} + Mg^{+2}) concentration which is harmful for drinking. Furthermore it produced sodicity in the soil when such water applied for irrigation purposes.

On other hand the groundwater samples were also test for the purpose of irrigation, sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) were analyzed. Values of SAR and RSC ranging between the 2.57 to 163.33 and 0.36 to 15.62 mg/L (Table 4) respectively (Golekar *et. al.*, 2013) which indicates that the quality of the area for irrigation along the drain is not good. Fig 7 and Fig 8 showed the geographical interpolation of SAR and RSC respectively.

Wastewater samples for biological oxygen demand (BOD) and chemical oxygen demand (COD) shows high pollution load. Values for BOD and COD ranging between the 201 mg/L to 332 mg/L (Ogunlaja *et al.*, 2009) and 260 mg/L to 485 mg/L (Paul *et al.*, 2012) respectively. Effluents coming from the sugar mill industry are worsening the condition of drain and effecting significantly on groundwater pollution. The statistical parameters were shown in (Table 4). Geographical interpolation of BOD and COD shown in Fig 13 and Fig 14 respectively.

Heavy metal concentration was found in the wastewater and sludge samples are high. The heave metal concentration was also cheek for the groundwater samples but the samples had no concentration where as the only five samples show very less amount of heavy metals up to 0.08 mg/L. Mean values

Table 3: Analysis of sludge samples collected from drain

Sr. #	Location	Longitude (E)	Latitude (N)	pH	EC	Pb	Cr	Cu	Cd	Zn
1	SS 1	72.74732500	31.23398333	9.20	8170	0.57	1.50	0.03	1.10	4.20
2	SS 2	72.74525556	31.23559444	9.53	6600	0.65	1.30	0.01	1.90	3.80
3	SS 3	72.76918611	31.24481389	9.10	8100	0.70	2.20	0.02	0.90	5.20
4	SS 4	72.73637500	31.26199444	8.99	8070	0.60	1.70	0.01	1.00	5.10
5	SS 5	72.74257778	31.26023056	9.07	7893	0.83	1.30	0.01	1.09	4.90

Table 4: Statistical analysis of various parameters for groundwater, wastewater and sludge

Analysis	GROUND WATER					WASTEWATER					SLUDGE				
	Mean	SD	Range		ANOVA	Mean	SD	Range		ANOVA	Mean	SD	Range		ANOVA
			Min.	Max.				Min.	Max.				Min.	Max.	
pH	8.00 ± 0.13	0.51	6.8	9.1	ns	9.17 ± 0.15	0.21	8.99	9.53	**	9.17 ± 0.15	0.210	8.99	9.53	**
EC	2375.80 ± 5.8	1620.93	239	6020	*	7627 ± 4	891.68	3805	5200	ns	7766.6 ± 3.20	660.1	5098	8178	ns
TDS	1520.80 ± 3.8	935.93	122	3010	*	4881 ± 2	348.68	6040	8140	ns	- -	- -	- -	- -	- -
TSS	582.23 ± 2.81	397.69	59.78	1474.9	ns	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
BOD	- -	- -	- -	- -	- -	290.6 ± 1.90	52.6	201	332	*	- -	- -	- -	- -	- -
COD	- -	- -	- -	- -	- -	395.4 ± 2.45	95.9	260	485	*	- -	- -	- -	- -	- -
Chloride	342 ± 3.38	253.68	32	960	ns	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
SAR	71.50 ± 3.38	36.01	2.57	166.33	ns	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
RSC	5.79 ± 0.92	3.76	0.36	15.62	*	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pb	- -	- -	- -	- -	- -	0.80 ± 0.092	0.074	0.7	0.91	ns	0.67 ± 0.10	0.100	0.57	0.83	ns
Cd	- -	- -	- -	- -	- -	1.21 ± 0. 92	0.35	0.77	1.60	**	1.19 ± 0.92	0.400	0.90	1.90	**
Cu	- -	- -	- -	- -	- -	0.016 ± 0.023	0.008	0.01	1.03	*	0.016 ± 0.02	0.008	0.90	1.90	*
Cr	- -	- -	- -	- -	- -	1.50 ± 0.23	0.008	1.00	2.10	*	1.6 ± 0.12	0.008	1.30	2.20	*
Zn	- -	- -	- -	- -	- -	4.64 ± 0.50	0.61	3.80	5.20	ns	4.64 ± 0.50	0.610	3.80	5.20	ns

* = Significant; ** = Highly significant; ns = non-significant

and statistical parameters of heavy metals (Cd, Pb, Cu, Cr and Zn) wastewater and sludge sample was shown in (Table 4). The concentration of cadmium (Cd) for wastewater and sludge was almost same varying in range of 0.77 mg/L to 1.60 mg/L and 0.90 mg/L to 1.90 mg/L (Ghannam *et al.*, 2012 and Adamu, 2012), for lead (Pb) 0.70 mg/L to 0.91 mg/L and 0.57 mg/L to 0.83 mg/L respectively (Adamu, 2012). Wastewater and sludge concenetration for cooper and zinc was found same (Table 2 and Table 3). For copper (Cu) wastewater and sludge samples varying in the range of 0.01 mg/L to 1.03 mg/L and 0.90 mg/L to 1.91 mg/L respectively (Ghannam *et al.*, 2012). Chromium (Cr) and zinc (Zn) analyzed for wastewater and sludge samples and showed the concentration ranging from 1.00 mg/L to 2.10 mg/L and 1.30 mg/L to 2.20 mg/L for chromium respectively (Golekar *et. al.*, 2013) and 3.8 mg/L to 5.2 mg/L for both wastewater and sludge samples (Ghannam *et al.*, 2012 and Adamu, 2012). Such a concentration found in the samples showing high level of pollution and bad conditions for the groundwater resources.
Geographical interpolation of heavy metal ions was shown in Fig 15 to Fig 22 for both wastewater and sludge.

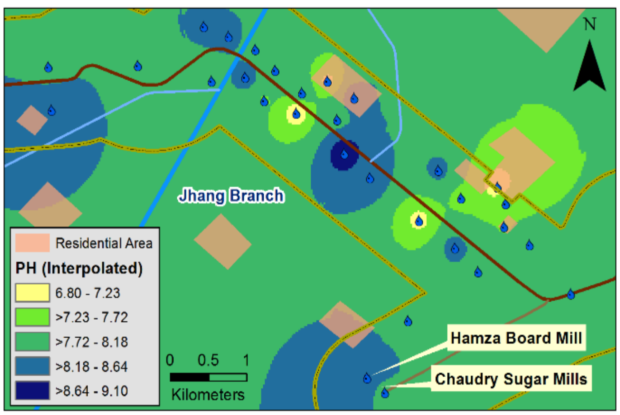

Figure 1: pH interpolation of groundwater samples

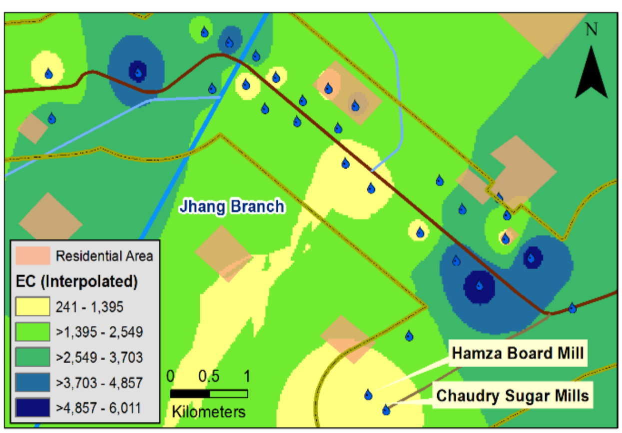

Figure 2: EC interpolation of groundwater samples

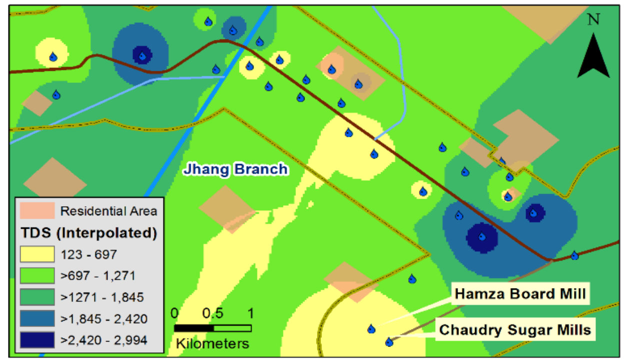

Figure 3: TDS interpolation of groundwater samples

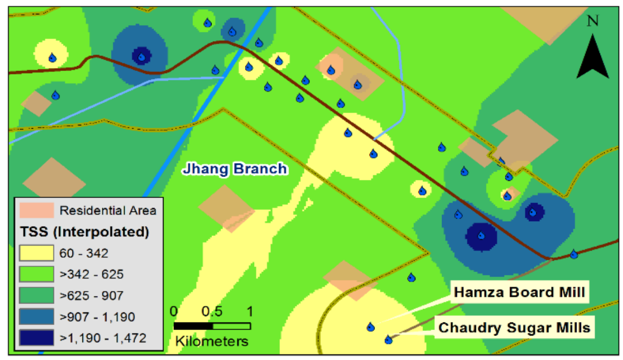

Figure 4: TSS interpolation of groundwater samples

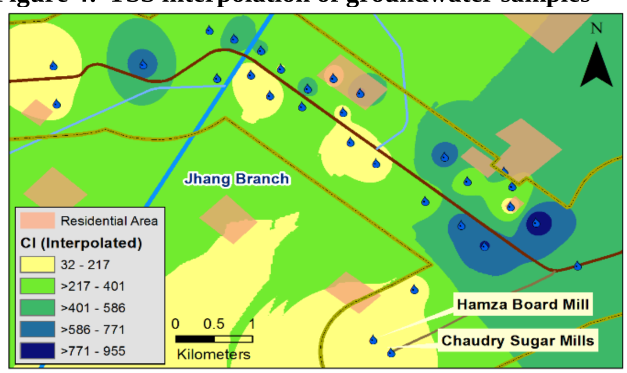

Figure 5: Chloride contents interpolation of groundwater samples

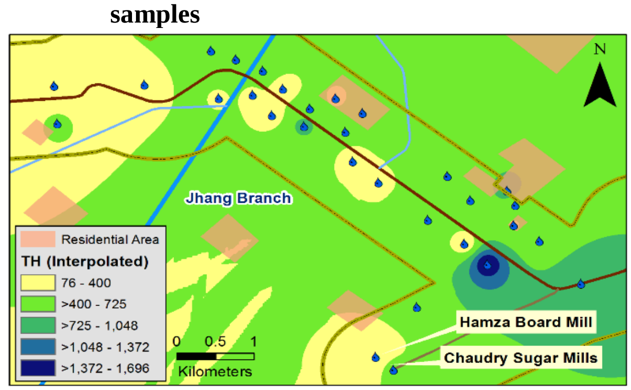

Figure 6: Total Hardness interpolation of groundwater samples

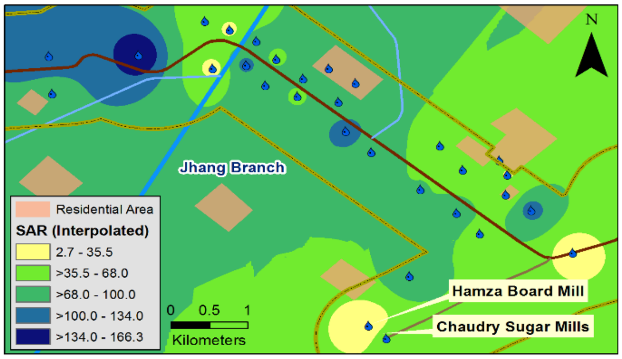

Figure 7: SAR interpolation of groundwater samples

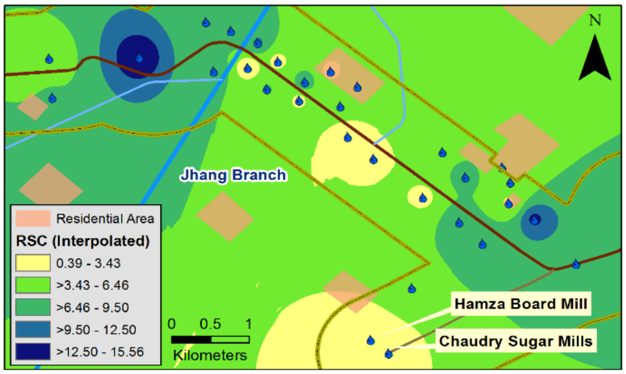

Figure 8: RSC interpolation of groundwater samples

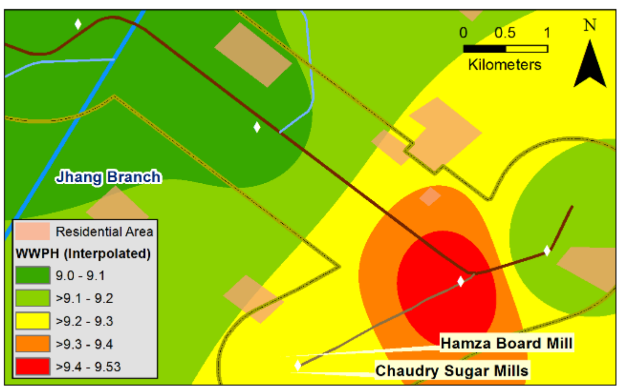

Figure 9: pH interpolation of Wastewater and Sludge

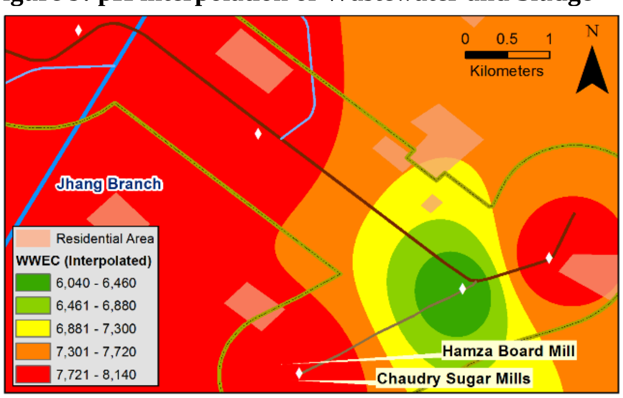

Figure 10: EC interpolation of Wastewater

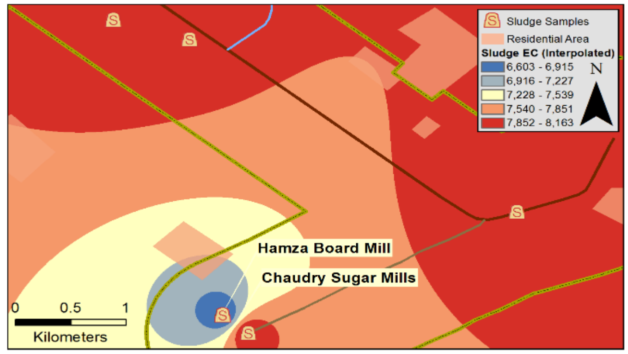

Figure 11: EC interpolation of Sludge

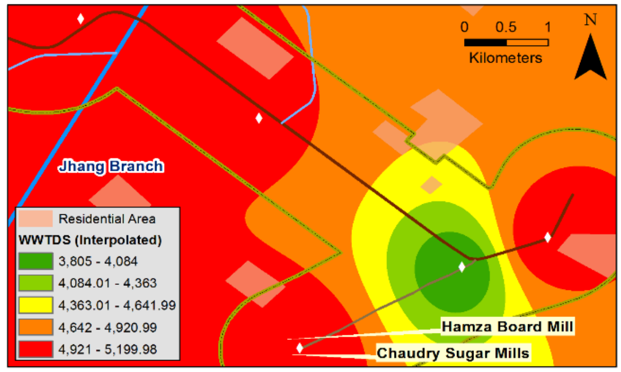

Figure 12: TDS interpolation of Wastewater

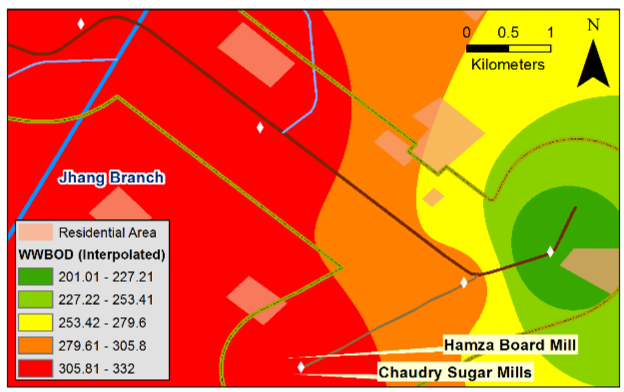

Figure 13: BOD interpolation of Wastewater

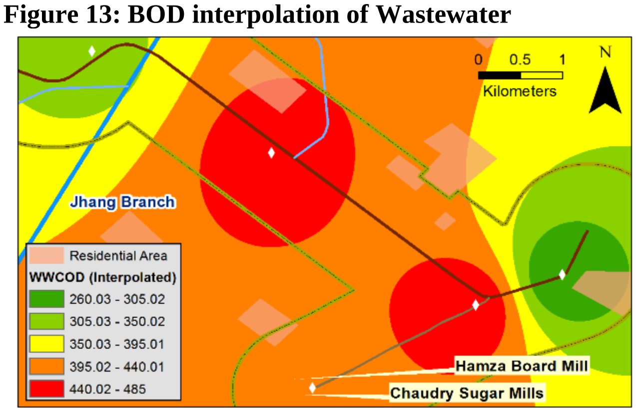

Figure 14: COD interpolation of Wastewater

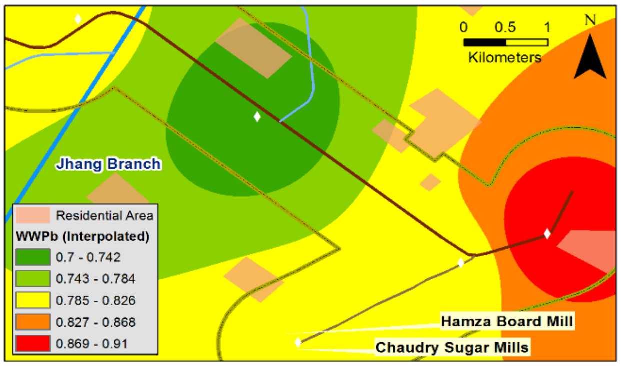

Figure 15: Lead (Pb) interpolation of Wastewater

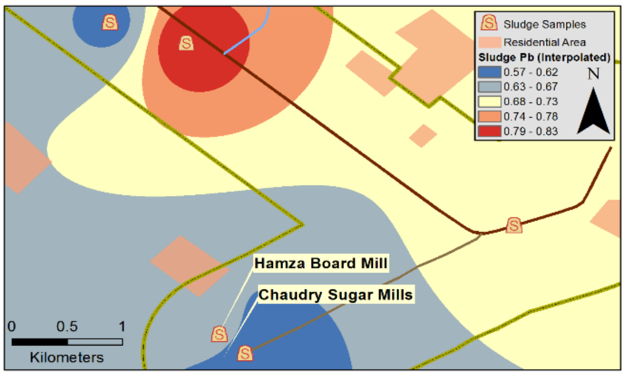

Figure 16: Lead (Pb) interpolation of Sludge

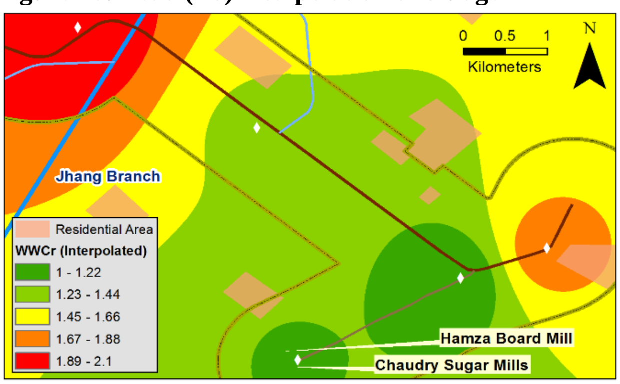

Figure 17: Chromium (Cr) interpolation of Wastewater

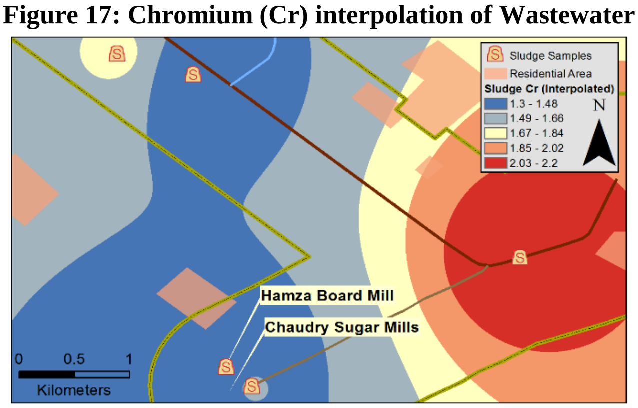

Figure 18: Chromium (Cr) interpolation of Wastewater

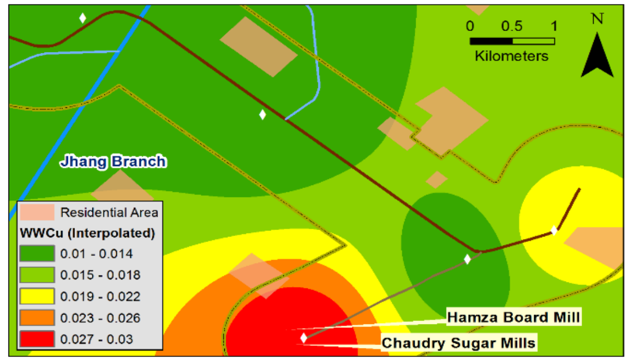

Figure 19: Cooper (Cu) interpolation of Wastewater and Sludge

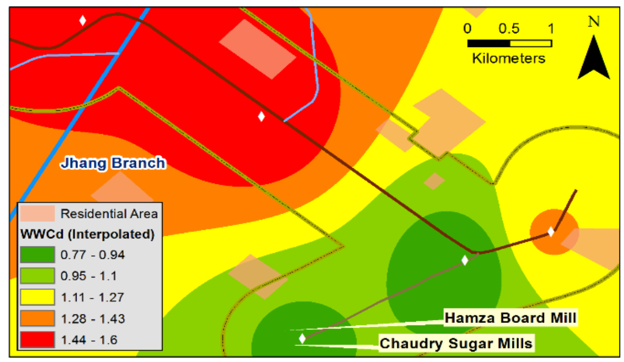

Figure 20: Cadmium (Cd) interpolation of Wastewater

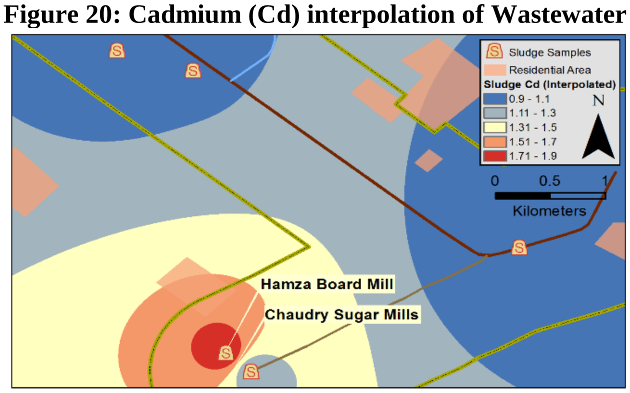

Figure 21: Cadmium (Cd) interpolation of Sludge

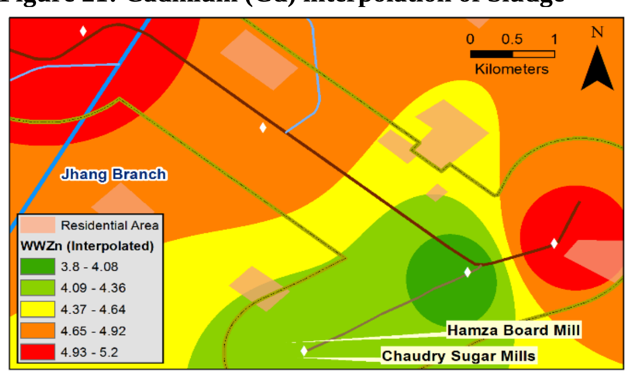

Figure 22: Zinc (Zn) interpolation of Wastewater and Sludge

Conclusion and Recommendations: Concluding the research, results showed the high level of contamination of heavy metals and other organic load in the drain emitting from the industries especially sugarcane industry. Sugarcane industry thronging the effluents in drain more in day time. The basic parameters of the ground water were changed due to wastewater of drain. The effluents passing through the drain polluting the groundwater resources and soil becomes slain which is reducing soil potential and crop yield as well. Geographical interpolation showed that the pollution effect is more toward the left side rather than the right side along the drain. Chemical parameters also described brackish quality of groundwater, however the some samples indicating best result for drinking and irrigation purposes. It is recommended that the tube well should be placed away from the drain at least 600 m or near the Jhang branch canal. Farmers should adopt such a crops that are salt tolerating and added nutrients that reduced the hardness of the soil like as Gypsum for saline soils. Government should make such polices that industries drained out their effluents after treating wastewater.

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